Submitted to:
US EPA Region 8
Denver, CO

Submitted by:
Atlantic Richfield Company
La Palma, CA
September 7, 2012

Ion Exchange Bench-Scale Test Work Plan
Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Rico, Colorado

Atlantic Richfield Company

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September 7, 2012

VIA EMAIL AND HAND DELIVERY

Mr. Steven Way
On-Scene Coordinator
Emergency Response Program (8EPR-SA)
US EPA Region 8
1595 Wynkoop Street
Denver, CO 80202-1129

RE: Ion Exchange Bench-Scale Test Work Plan, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Rico, Colorado
EPA Unilateral Administrative Order, Docket No. CERCLA-08-2011-0005

Dear Mr. Way:

A digital file in PDF format of the Ion Exchange Bench-Scale Test Work Plan, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Rico, Colorado, dated September 7, 2012, is being submitted to you today via email. Three (3) hard copies of the Work Plan will be hand-delivered to your office no later than September 10.

Atlantic Richfield Company (AR) is submitting this Work Plan responsive to requirements in Task E – Source Water Investigations and Controls / Subtask E2 – Additional Investigations of the Remedial Action Work Plan accompanying the Unilateral Administrative Order for Removal Action, Rico-Argentine Site, Dolores County, Colorado, US EPA Region 8, Docket No. CERCLA-08-2011-0005.

If you have any questions or comments, please feel free to contact me at (714) 228-6770 or via e-mail at Anthony.Brown@bp.com.

Sincerely,

Anthony R. Brown

Tony Brown
Project Manager
Atlantic Richfield Company

Enclosure (Ion Exchange Bench-Scale Test Work Plan)

cc:

Terry Moore, Atlantic Richfield Company
Sandy Riese, EnSci, Inc.
Chris Sanchez, Anderson Engineering Company, Inc.
Dave McCarthy/Copper Environmental Consulting, LLC
Terry McNulty/T.P. McNulty and Associates, Inc.
Marc Lombardi, AMEC
Tom Kreutz, AECOM Technical Services, Inc. (without enclosure)
Doug Yadon, AECOM Technical Services, Inc. (without enclosure)

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1.0 Introduction

AECOM Technical Services, Inc. (AECOM), on behalf of Atlantic Richfield Company (AR), has prepared this Ion Exchange (IX) Bench-Scale Test Work Plan (Work Plan) to evaluate the use of ion exchange as an alternative treatment process to reduce dissolved metals concentrations in water flowing within the Blaine Underground Workings and discharging from the St. Louis Tunnel of the Rico-Argentine Mine Site – Rico Tunnels Operable Unit (OU01). Figure 1 illustrates the location of the Blaine and St. Louis Tunnels relative to the Town of Rico, Colorado, and the St. Louis Ponds. Historically, the Blaine Tunnel provided drainage for the Rico-Argentine Mine and interconnected mine workings above the Blaine level, and is believed to have discharged directly to Silver Creek. At present, a permanent cofferdam approximately 350 feet into the tunnel from the portal reportedly diverts the discharge to an incline within the mine known as the Morris Cook, and through interior workings (inferred based on tracer tests by EPA in 2011 to include the 517 Shaft) to eventually emerge at the St. Louis Tunnel portal area.

The first step in the IX testing program involved collecting water samples from selected locations on September 6, 2012. Bulk samples were collected from the St. Louis Tunnel discharge water at DR-3, the St. Louis Tunnel upgradient of the portal blockage through the AT-2 drill hole, and the Blaine Tunnel. A smaller sample of water was collected from the 517 Shaft in the Rico-Argentine Mine workings. A large bulk sample of Blaine Tunnel water was originally collected during the Blaine Base Flow Test. These waters will be used for a laboratory bench-scale evaluation of selected IX resins to identify those resins best-suited for removing metals, primarily cadmium and zinc, from the mine waters. If warranted, the results of the initial laboratory bench-scale studies would be used to design a program for subsequent long-term laboratory column testing and possibly field pilot-scale testing of one or more of these waters during 2013.

1.1 Scope

This Work Plan complements other past and current efforts to intercept Blaine Tunnel and St. Louis Tunnel flows and characterize the water quality and quantity conditions for these water sources. The scope of this Work Plan is focused on the potential application of IX treatment to remove heavy metals of concern, primarily cadmium and zinc, from Blaine Tunnel flows, "interior" St. Louis Tunnel water via the AT-2 drill hole, "exterior" St. Louis Tunnel discharges at DR-3, and 517 Shaft water. This Work Plan describes laboratory testing of these waters using bench-scale equipment and techniques to evaluate alternative IX resin formulations for removal of key metals of concern from the waters. One or more IX resins will be selected based on their ability to effectively remove the metals of interest.

Depending on the results of the initial bench-scale testing described in this Work Plan, one or more IX resins may be identified as candidates for subsequent evaluation in the field using a pilot-scale operation that would divert a small (3-5 gallons per minute) portion of the Blaine Tunnel, AT-2 drill hole, and/or St. Louis Tunnel flow (in sequential order to be determined if more than one source is to be tested) and route this flow through a portable pilot-scale plant on-site that will test the selected IX resins under ambient conditions.

1.2 Responsibilities

Bulk samples were collected from the St. Louis Tunnel discharge water at DR-3, the St. Louis Tunnel upgradient of the portal blockage through the AT-2 drill hole, and the Blaine Tunnel under the direction of AECOM with field implementation by Anderson Engineering Co., Inc. (AECI). A smaller sample of water was collected from the 517 Shaft in the Rico-Argentine Mine workings by AMEC.

Hazen Research, Inc. (Hazen), under the direction of AECOM and AR, will use these water samples for bench-scale testing of selected IX resins, as discussed below under Section 3.0, Investigations. If subsequent field pilot-scale testing is to be implemented, Hazen would provide and operate a field pilot-scale IX column test facility in conjunction with AECOM personnel and in accordance with a protocol to be developed after completion of the bench-scale testing. AECI personnel would be responsible for diversion of an independent flow of 3-5 gpm from the Blaine Tunnel in coordination with underground support by the Colorado Division of Reclamation and Mine Safety (CDRMS), and/or the St. Louis Tunnel either at DR-3 or via drill hole AT-2.

2.0 Objectives

The purpose of this study is to evaluate IX resin metals removal from waters in the Rico-Argentine Mine, with the ultimate goal of reducing the dissolved metals loading in water that emerges from the St. Louis Tunnel; this loading is contributed by source flow from the Rico-Argentine Mine via the Southeast Crosscut, as well as the Mountain-Spring Wellington Mines via the Northeast Crosscut. The effort is designed to provide information on treatment performance specifically for IX resins, as well as data to be used to support overall design of a local treatment facility for source control at the Rico-Argentine Mine, and/or a treatment facility at the St. Louis Tunnel portal to treat accumulated discharges from the mine workings, if indicated by the results of this study to be a viable treatment alternative. Water in the St. Louis Tunnel consists of water within the mine that may be similar to water sampled from the AT-2 drill hole, and water that has left the mine and been chemically altered by flow through colluvium/alluvium and/or reaction with atmospheric oxygen to produce the water sampled at DR-3. Water from the AT-2 drill hole will be tested because it represents accessible mine water. Water from the DR-3 discharge location at the St. Louis Tunnel will be tested because it represents water that has been naturally chemically altered through oxidation, reducing metals loading after emergence from the mine. The EPA Remedial Action Work Plan currently requires study of the installation of hydraulic controls within the rock portion of the St. Louis Tunnel (i.e., currently envisioned as a water-tight bulkhead with a valved pipe penetration). AT-2 water thus may be representative of water that would be controlled by the constructed bulkhead and discharged through a valved pipe to the point of treatment. The DR-3 water represents the water that currently emerges from the mine and may require final "polishing" to remove metals to levels meeting the Remedial Action Work Plan objectives and ARARs.

Specifically, the primary objective of this study is to assess the performance of alternative IX resins using bench-scale techniques to confirm the applicability of this technology for metals removal from the waters of the Rico-Argentine Mine. If IX treatment appears sufficiently promising, the results of this study would also support design of a subsequent on-site performance evaluation of a selected IX resin(s) for metals removal from water representative of anticipated long-term discharge from the Blaine Tunnel and/or the St. Louis Tunnel.

3.0 Investigations

The investigations described in this section of the Work Plan focus on the work flow and general guidelines to be used for the bench- and field pilot-scale IX resin evaluation testing. The investigations have been divided into the following tasks:

Task A – Water Sampling and Analysis
Task B – Laboratory IX Resin Bench-Scale Testing
Task C – Data Reduction, Evaluation, and Report Preparation

3.1 Task A – Water Sampling and Analysis

Bulk samples were collected from the St. Louis Tunnel discharge water at DR-3 (25 gallons), the St. Louis Tunnel upgradient of the portal blockage through the AT-2 drill hole (35 gallons), and the Blaine Tunnel (35 gallons) on September 6, 2012. A smaller sample (5 gallons) of water was collected from the 517 Shaft in the Rico-Argentine Mine workings, also on September 6. A large bulk sample (approximately 200 gallons) of Blaine Tunnel water was previously collected during the Blaine Base Flow Test.

These samples will be analyzed for the constituents listed in Table 1 in accordance with the Rico SAP, QAPP, and SOPs. The water quality results will be utilized in the planning and implementation of the testing described in this Work Plan. The results of these analyses will also be compared to previous analyses of these same water sources to assess to the extent the available results allow the variability in water quality at these locations.

3.2 Task B – Laboratory IX Resin Bench-Scale Testing

Samples collected as part of Task A will be used for bench-scale testing of selected IX resins to confirm the practical exchange capacities for and treated water concentrations of zinc, cadmium, and other heavy metals to be determined after analysis of the St. Louis Tunnel, Blaine Tunnel, 517 Shaft, and AT-2 water samples. A Laboratory Implementation Plan is being prepared to detail the protocols to be followed in evaluation of the selected IX resins as described under this Task B.

Task B-1: Selection of IX Resin Candidates

Candidate IX cation exchange resins will be identified based on manufacturers' recommendations, a literature review of IX resins used for transition metals removal from acid mine drainage, and computer-modeled performance projections for water similar to the Blaine Tunnel, 517 Shaft, AT-2, and St. Louis Tunnel discharge waters. It is anticipated that up to four (4) IX resins may be selected for evaluation.

Task B-2: Sample Water Pre-Treatment Evaluation

Prior to the IX Resin Isotherm Evaluation discussed in Task B-3 below, the sample waters from the Blaine Tunnel, AT-2 drill hole, the St. Louis Tunnel discharge (as sampled at DR-3), and the 517 Shaft will be evaluated for the necessity of pre-treatment in order for the IX resins to effectively remove cadmium and zinc and other metals to be selected following analysis of the waters. Pre-treatment options will be considered and evaluated if it is deemed necessary to:

- Adjust pH,
- Reduce the iron loading in the water prior to isotherm evaluation,
- Reduce calcium and/or sulfate concentration levels, or

- Make other chemical adjustments to the Blaine Tunnel, St. Louis Tunnel discharge, AT-2, or 517 Shaft waters prior to the Isotherm Evaluation in Task B-3.

Task B-3: IX Resin Isotherm Evaluation

Once the candidate resins are identified, a fixed volume of pre-treated (if/as necessary) Blaine Tunnel, St. Louis Tunnel discharge, AT-2, and 517 Shaft water will be mixed with a specified mass of the resin to determine an IX resin exchange isotherm. After the resin is added to the water, samples will be periodically taken to compare the concentration of the heavy metals in the solution remaining at any given time to the starting solution concentration. An isotherm will be developed for each metal of concern for each IX resin tested showing the ratio of the initial concentration, $C_{(i)}$, to the concentrations at specified sample times, $C_{(t)}$, until an equilibrium condition is achieved. The primary metals of concern will be cadmium and zinc, but other metals may be evaluated based on the results of Task A.

Task B-4: IX Resin Column Testing

The isotherm data may confirm that one or more of the candidate resins will perform as projected and provide adequate removal of one or more of the metals of concern for the Blaine Tunnel water. If so, further testing of the selected IX resins will consist of column metal removal testing where additional Blaine Tunnel water, pre-treated as needed, will be passed through single-column IX resin samples at flow rates per unit of area representative of full-scale systems to determine the expected treated water quality and the breakthrough characteristics for each of the selected IX resins. Water samples will be analyzed for the constituents in Table 1 before the water is run through the columns; effluent water leaving the test IX resin columns will also be analyzed for the same constituents to determine the effectiveness of metals removal and removal of other cations from the waters tested. As part of the Resin Column Testing, regeneration of the selected resins will be evaluated to determine the time and cost involved in regeneration. If the results of Task B-3 indicate that other of the sampled waters may perform well with IX treatment, additional column testing could be performed on large bulk samples that would be acquired in the Spring of 2013.

3.3 Task C – Data Reduction, Evaluation, and Report Preparation

Data collected during the bench testing of the IX resins will be reduced and evaluated following completion of the tests. The analytical results from Task B-4 will be used to develop a flow sheet and to calculate a mass balance for the IX resins found suitable for removing cadmium, zinc, and other metals from the Blaine Tunnel water.

Results of the bench testing will be summarized and included in the Subtask E3 *Evaluation of Hydraulic Controls Alternatives* report currently due January 31, 2013, per the revised EPA Work Plan schedule. Operational records of the bench tests, including equipment and techniques used, will also be summarized and included in the report.

4.0 Schedule

The proposed schedule for implementation of the work under the Ion Exchange Bench-Scale Work Plan is provided in Table 2. Water sampling and transport to the laboratory was completed on September 7, 2012. Initial source water chemistry analyses under Task A and selection of IX resin candidates under Task B will be completed by early October. Pre-treatment evaluations under Task B will commence immediately following selection of IX resin candidates. Initiation of the IX resin isotherm bench-scale testing is scheduled to begin in mid-October, overlapping the pre-treatment evaluations, and be substantially completed in early November. IX resin column testing of Blaine Tunnel water, if implemented, would be performed during the month of November. A final report on the bench-scale evaluation of the IX resins would be submitted to the EPA on January 31, 2013.

If additional IX resin column testing of waters other than the Blaine Tunnel is indicated by the results of this study, large bulk samples would be acquired and the testing performed in the Spring of 2013. Similarly, if pilot testing of any of the candidate waters tested under this Work Plan is indicated, that field-scale testing would be performed during the Spring and early Summer of 2013.

TABLES

Table 1: Analytical Parameters and Procedures Summary

Parameter	Minimum Detection Limit (MDL)	Method
Field Parameters		
pH (s.u.)	+/- 0.01 pH	EPA 150.2
Temperature	+/- 1°C	Standard Method 2550
Conductivity (µmhos/cm)	+/- 2% Full Scale	EPA 120.1
Dissolved Oxygen	+/- 2% Full Scale	SM 4500-OG
ORP (Redox Potential)	N/A	Ag/AgCl Probe
Non-Metals		
Alkalinity (mg/L as $CaCO_3$)	RL – 20 mg/L	EPA 310.1
Hardness (mg/L as $CaCO_3$)	RL – 0.5 mg/L	SM 2340B
Total Dissolved Solids	RL – 5.0 mg/L	SM 2540C
Total Organic Carbon	0.5 mg/L	EPA 415.1
Total Suspended Solids	RL – 5.0 mg/L	SM 2540D
Bicarbonate	TBD	SM 2320B
Cyanide	RL – 0.005 mg/L	EPA 335.4
Fluoride	TBD	EPA 300.0
Nitrate	TBD	EPA 300.0
Salinity	RL – 6 mg/L	SM 2510B (calculated)
Silica	0.1 mg/L	ASTM D859
Sulfate	RL – 1 mg/L	EPA 300.0
Sulfides	0.05 mg/L	EPA 376.2
Total and Dissolved Metals		
Aluminum	2 µg/L	EPA 200.8
Antimony	0.07 µg/L	EPA 200.8
Arsenic	0.09 µg/L	EPA 200.8
Barium	0.08 µg/L	EPA 200.8
Beryllium	0.02 µg/L	EPA 200.8
Cadmium	0.03 µg/L	EPA 200.8
Calcium	10 µg/L	EPA 200.8
Chromium	0.25 µg/L	EPA 200.8
Cobalt	0.05 0 µg/L	EPA 200.7
Copper	0.07 µg/L	EPA 200.8
Iron	4.67 µg/L	EPA 200.8
Lead	0.05 µg/L	EPA 200.8
Magnesium	2.5 µg/L	EPA 200.8
Manganese	0.17 µg/L	EPA 200.8
Mercury	0.049 µg/L	EPA 245.1
Nickel	0.07 µg/L	EPA 200.8
Potassium	10 µg/L	EPA 200.8
Selenium	0.22 µg/L	EPA 200.8
Silver	0.25 µg/L	EPA 200.8
Sodium	25 µg/L	EPA 200.8
Thallium	0.05 µg/L	EPA 200.8
Vanadium	0.05 µg/L	EPA 200.8
Zinc	2.5 µg/L	EPA 200.8

Table 2: Schedule

	2012																2013			
	September				October				November				December				January			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
TASK A: WATER SAMPLING AND ANALYSIS																				
Field Water Sample Collection and Transport																				
Confirmatory Sample Analysis and QA/QC																				
TASK B: LABORATORY IX RESIN BENCH-SCALE TESTING																				
Selection of IX Resin Candidates																				
Sample Pre-Treatment Evaluation																				
IX Resin Isotherm Analysis																				
IX Resin Column Testing																				
Data Analysis and QA/QC																				
TASK C: DATA REDUCTION, EVALUATION, AND REPORTING																				
Data Reduction and Evaluation																				
Summary Report																				
Draft Report (Client Review)																				
Final Report to EPA																				

FIGURES

IMAGERY COURTESY OF GOOGLE EARTH PRO

RICO-ARGENTINE SITE-OU01

ION EXCHANGE WORK PLAN

FIGURE 1 - RICO-ARGENTINE MINE SITE

AECOM

JUNE 18, 2012

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